LIFE HISTORY OF THE WESTERN NORTH AMERICAN GOBY, *CORYPHOPTERUS NICHOLSII* (BEAN)

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ABSTRACT.—The life history of *Coryphopterus nicholsii* was investigated by field and laboratory studies based primarily on a population at Laguna Beach, California. The species occurs in depths of 6m to more than 60m on rock reefs, where it utilizes holes and undercuts in the rock for shelter. Crustaceans (amphipods and copepods) are the major food item; mollusks are also taken in significant numbers. Echinoderms, annelids, mollusks, bryozoans and various eggs are more important food items during fall and winter seasons. Pelagic prejuveniles feed only on copepods. In the study area the sex ratio is 1.7 females : 1 male. Juveniles were first observed on the reefs in February 1967. Length-frequencies and observed scale age groups show 4 to 5 age groups. *Paralabrax nebulifer* and *Lythrypnus dalli* prey on *C. nicholsii.* Sexual dimorphism occurs in the genital papilla, size, length of dorsal and anal fins, and nuptial color of pelvic fins. Breeding extended from mid-February to late August in 1967. Males became ripe at 55 mm, in age-group II and III. Females became ripe at about 47 mm, in age-group II. Ripe ovaries contain two egg groups: ripe and unripe. The total number of ripe eggs in 4 individuals ranged from 3274 to 4788. The spindle-shaped fertilized eggs are attached directly to the overhanging rock surface of the nest. The larvae are pelagic and prejuveniles have been taken far from shore. Juveniles as small as 21.8 mm were found on the reefs from February through August, 1967. The male prepares and guards the nest. In courtship the male rushes at the female and also rises off the bottom a few centimeters with the fins spread, before it settles back down. This species is territorial. A hierarchy is established in the laboratory aquarium.

The gobies constitute a widely divergent group of fishes, the suborder Gobioidei. They occur in the tropical, temperate, and subboreal zones throughout the world, avoiding only the polar regions. Most gobioids are marine, but some inhabit fresh water, including a few in torrential streams.

Gobies of the New World genus *Coryphopterus* are common in the inshore waters of both the tropical western Atlantic and eastern Pacific, inhabiting holes in shallow water coral reefs or rocks. Nine species have been described in the tropical and subtropical western Atlantic. Of the two eastern Pacific species, *C. urospilus* is tropical, but *C. nicholsii* (Bean), the subject of this paper, ranges widely from subtropical to subboreal waters.

STUDY AREA

An intensive field study of *Coryphopterus nicholsii* was conducted at Laguna Beach, Orange Co., California from September 1966 through January 1968. The study area consisted of two rock reefs: one a shallow, breaking reef which extends down to 10m is approximately 90m offshore; the other varies from 15 to 25m in depth, and is approximately 1200m from the shallow reef, and 800m offshore. Each is approximately 45m long, and is surrounded by sand bottom.

METHODS AND MATERIALS EXAMINED

The population at Laguna was sampled at weekly or biweekly intervals with the use of SCUBA. Most specimens were collected with a slurp gun, although some were taken with "Chem-Fish." Other collections were made in California at Malibu and Palos Verdes, Los Angeles Co.; at Cameo Shores and Aliso Creek, Orange Co.; and at La Jolla, San Diego Co.; and in Baja California, Mexico, at Punta Banda (SW side).

Methods of counting serial parts and taking measurements follow those of Hubbs and Lagler (1958), except that the caudal ray counts follow the methodology of Ginsburg (1945). The last two ray bases of the dorsal and anal fins were counted as one ray. All measurements were taken with dial calipers to the nearest 0.1 mm. Proportions, obtained arithmetically, are presented as ranges and means. All measurements of body length are standard lengths (S.L.).

Museum specimens examined were from the following collections: Stanford University (SU); California Academy of Sciences (CAS); Scripps Institution of Oceanography (SIO); University of California, Los Angeles (UCLA); Los Angeles County Museum of Natural History (LACM); and California State College, Long Beach (CSCLB).

BLUESPOT GOBY
Coryphopterus nicholsii (Bean)

Gobius nicholsii.–Bean, 1881: 469 (original description; type locality, Departure Bay, British Columbia; 20 fm.). Jordan and Evermann, 1898: 2218 (specimens recorded from coast of British Columbia). Halkett, 1913: 30, 95 (listed; coast of British Columbia). Fowler, 1923: 293,300 (Malibu Cove, Point Firmin, Newport, Catalina, Isthmus Harbor, Cataling Harbor, Avalon, Santa Cruz, and La Jolla, California). Clemens and Wilby, 1946: 168 (description of type).

Gobius nicholsi.–Jordan and Gilbert, 1882: 946 (coast of British Columbia; description). Jordan and Eigenmann, 1886: 489, 494, 516, 517 (coast of British Columbia; analysis; listed). Jordan, 1885: 893 (105) (listed). Eigenmann and Eigenmann, 1888: 59 (California; listed). Eigenmann and Eigenmann, 1892: 354 (San Diego, California). Eigenmann, 1892: 130, 159 (Point Loma, California). Jordan and Starks, 1895: 838 (Vancouver Island, British Columbia; listed). Jordan and Evermann, 1896: 456 (coast of British Columbia; listed). Gilbert and Starks, 1904: 176 (mentions *Gobius nicholsi* in comparing dermal fold of *Microgobius emblematicus*). Starks, 1911: 211 (listed; San Juan Islands, Washington). Bean and Weed, 1919: 79 (3 specimens – 33, 43, and 47 mm long; taken at Ucluelet, Vancouver Island, British Columbia, during low tide; June-July, 1909).

Gobius nicholsoni (sic).–Eigenmann, 1890: 66 (taken in deep water by the Albatross off Point Loma, California). Eigenmann, 1909: 65 (off Point Loma, California).

Rhinogobius nicholsii.–Starks and Morris, 1907: 223 (San Pedro, California). Starks and Mann, 1911: 16 (San Diego, California; 50 fm.).

Rhinogobius nicholsi.–Snyder, 1913: 459 (Pacific Grove, California; description; taken from 10-15 fm.). Gilbert, 1915: 359 (abundant in harbor at Avalon, Catalina Island; taken in shallow water at Monterey, California). Kincaid, 1919: 40 (San Juan Islands, Washington).

Rhinogobiops nicholsii.–Hubbs, 1926: 2 (type of genus; description; Santa Barbara Channel and southwest of Newport, California). Hubbs, 1928: 15 (listed). Ulrey and Greeley, 1928: 20 (Catalina Island, Huntington Beach, Malibu, Newport, Point Firmin, and Santa Cruz, California). Jordan, Evermann, and Clark, 1928: 440 (coast of British Columbia, south to southern California). Ulrey, 1929: 10 (listed). Wismer and Swanson, 1935: 343; Table 19 (San Juan Channel, Washington; depth 8-12m; estimate of numbers of *R. nicholsii* at 17 fish/2000m^2 on dredge and trawl catches). Schultz, 1936: 122, 191; fig. 16 (key; figure showing ventral side; British Columbia to southern California). Barnhart, 1936: 81; fig. 245 (description; San Clemente Island to British Columbia; sometimes taken in more than 2100 feet). Schultz and DeLacy, 1936: 137, 213 (British Columbia to southern California; Hood's Canal near Holly, Washington; marine; not rare; San Juan Island, Washington). Clemens and Wilby, 1946: 5, 29, 167-168; fig. 103 (key; listed; range, English and Nanoose bays, Barkley Sound at Ucluelet, Esperanza Inlet on west coast of Vancouver Island, Skidegate Channel, Queen Charlotte Islands; 20 fm. or more; description). Limbaugh, 1962: 552 (La Jolla, California; colonizing newly exposed reefs).

Coryphopterus nicholsii.–Ginsburg, 1938: 113 (no locality; differences from *Coryphopterus urospilus*). Ginsburg, 1945: 136, 137 (*C. nicholsii* used in study of fin-ray count methodology). McAllister, 1960: 38 (listed). Miller and Lea, 1972: 186 (figure; description; key; range – south of Point Rompiente, Baja California, to Skidegate Channel, Queen Charlotte Island, British Columbia; depth 5 to 80 feet).

Coryphopterus nicholsi.–Hubbs and Follett, 1953: 34 (listed). Limbaugh, 1955: 26, 35, 120 (southern California; observed in "sand-bottom holdfast biotope" and "kelp rock-bottom biotope"; preferred southern California habitat sand near rocks; 1-180 feet; description; observed at following localities – Pacific Grove, Yankee Point, Goleta, Point Dume, El Segundo, Rocky Cove, Newport Beach, San Clemente, and La Jolla; and at San Miguel, Santa Rosa, Santa Cruz, Anacapa, Santa Catalina, Los Coronados, and San Martín islands). Böhlke and Robins, 1960: 103, 105 (key; characteristics; discussion of genus). Ebert and Turner, 1962: 249-252 (ecology; breeding habits; behavior; description of eggs and embryos). Pequegnat, 1964: 272 (Corona del Mar, California; abundance on reef). Carlisle, Turner and Ebert, 1964: 15, 28, 73, 77 (listed; observed on artificial reefs and offshore oil installations, and in Santa Monica Bay, California; spawned on Redondo Beach, California artificial reef; listed – Seal Beach, Rincon, Summerland, Redondo Beach, and Paradise Cove, California). Best and Oliphant, 1965: 101 (listed; Point Arguello, California). Turner, Ebert and Given, 1965: 109, 112 (listed, San Elijo Lagoon, San Diego County, California). Berry and Perkins, 1966: 676 (distribution of pelagic prejuveniles). Turner, Ebert and Given, 1966a: 16, 17, 18, 19, 26-27, 29; tables 1-4 (abundance; distribution on benthic quadrats; listed as abundant; Point Loma, California). Turner, Ebert and Given, 1966b: 40, 47 (distribution around Orange Co., California sewer outfall pipeline; relative abundance of goby in vicinity of outfall). McCart, 1967: 433-434 (scale regeneration). Fitch, 1967: 4, 16; fig. 3 (lower Pleistocene otoliths). Fitch, 1968: 2, 21-22; fig. 2s (early Pleistocene otoliths). Turner, Ebert and Given, 1969: 185 (habits on southern California artificial reefs). Macdonald, 1972: 91 (cephalic-lateralis system). Quast, no date (a): 4, 6; table 1 (listed among species ranging from boreal into temperate waters; British Columbia through north temperate; 0-130 feet; listed as member of southern California rocky-inshore zone fauna).

Bohlke and Robins (1960) referred to this species as *Coryphopterus nicholsi.* Although it stands alone in the group, Bohlke and Robins accept it in *Coryphopterus.* They indicated that should *C. nicholsii* be treated as subgenerically distinct, the name *Rhinogobiops* Hubbs would apply.

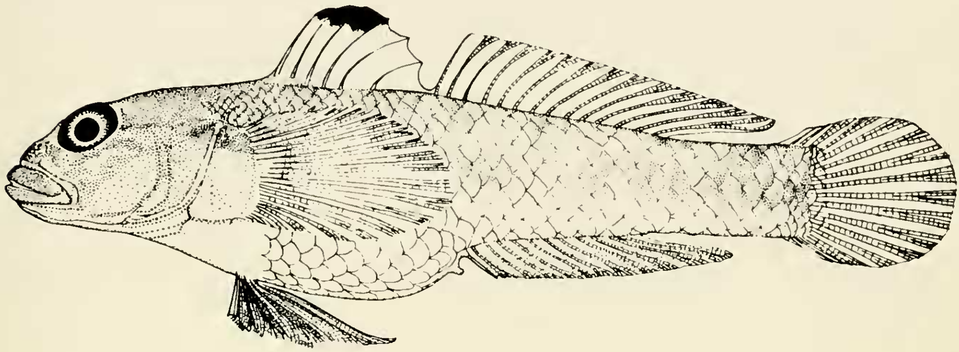


Figure 1. *Coryphopterus nicholsii.* Adult male, 86.5 mm in standard length, from Laguna Beach, Orange Co., California.

Diagnosis.–Coryphopterus nicholsii (Fig. 1) is easily distinguished from all other species of *Coryphopterus* by having more soft dorsal, anal, and pectoral rays, more scales, and in having a narrow wedge of scales reaching a point above the anterior margin of the opercle.

Description.–It has an elongate, moderately stout body. Greatest body depth 4.1-6.1 (5.17) in standard length. Body slightly compressed, width 5.7-10.6 (7.26) in standard length. Head moderate, wider than deep; head width 1.2-2.1 (1.50) in head length; head length 3.0-4.2 (3.56) in standard length. Cheeks not tumid. Mouth small and terminal. Lower jaw projecting. Maxilla not reaching to point below anterior margin of eye, 1.9-3.2 (2.58) in head length. Jaw teeth conical, in bands, enlarged in both an outer and inner row. Tongue truncate at tip. Eye directed superolaterally and large (diameter 2.5-4.3 (3.42) in head length). Bony interorbital very narrow. A high, thin and nearly vertical crest on top of head from behind eyes to origin of spinous dorsal fin. Rows of papillae on sides of head moderately developed. No barbels (Fig. 12). Slit behind fourth gill-arch reduced; pseudobranchiae exposed. Branchiostegals 5 (1 on epihyal). Pelvic fins fully united, free from belly, each with I, 4 rays. Pectoral fins with 21-24 (22.3) rays, none silky. Dorsal fins barely separated, VI-I, 12-15 (13.8). Caudal fin broadly rounded, 17: 12 segmented, branched rays and a variable number of segmented, unbranched rays and simple (procurrent) rays. Some specimens with 2 above and 1 below segmented, unbranched rays, plus 2 simple rays below occur about as frequently as those with 2 above and none below segmented, unbranched rays, plus 3 simple rays – 1 above, 2 below. Rarely the caudal elements composed of 12 branched, segmented rays with above and below 1 unbranched, segmented ray, plus 1 above and 2 below simple rays. Anal I, 11-14 (12.1). Body completely scaled except in predorsal midline. Head scaleless. Scales of sides each with a comb-like row of marginal spines, a submarginal focus, and basal radii. Scales in oblique rows, 23-28 (25.6) at midline. No lateral line. Shoulder girdle without papillae. Color: pale orange-olive or light yellow, with irregular vertical purplish brown streaks developed at time of death or in social interaction. Body irregularly flecked with metallic blue-green. Iridescent stripe below eye, giving rise to vernacular name – bluespot goby. Tip of first dorsal jet black. Pelvic fin of breeding male black.

OCCURRENCE

Coryphopterus nicholsii ranges from Point Rompiente (27°N), Baja California to Skidegate Channel (53°N), Queen Charlotte Island, British Columbia (Miller and Lea, 1972; McCart, 1967). It is common in this area and its range may be more extensive than is currently realized.

Otoliths of *C. nicholsii* have been found in many southern California Pliocene and Pleistocene deposits. More than 1,700 have been recovered from the Lomita marl (Pliocene) at San Pedro, and others have come from Timms Point silt, San Pedro sand (Lower Pleistocene) and Baldwin Hills, Los Angeles (Upper Pleistocene) (Fitch, 1967, 1968).

GENERAL ECOLOGY AND NATURAL HISTORY

Coryphopterus nicholsii inhabits shallow water, from 6m to more than 60m. After a pelagic oceanic existence as larvae and early juveniles, individuals assume a benthic habit. The preferred habitat appears to be a rock-reef area, but small groups of rocks on the open sand are also inhabited. The greatest concentrations occur near the periphery and in the channels of the reef, where the rock meets the surrounding sand bottom; in these areas there are numerous undercuts and holes, into which this goby can find safety. It is seldom found more than 25 cm from protective cover, but is common on the open sand or rubble bottom in front of its shelter. The open area around the hole serves as a feeding and display site.

Coryphopterus nicholsii is also found over the tops of reefs, particularly in areas having many holes, ledges, or thick gorgonian cover. Using the protective cover of the gorgonian canopy, individuals may venture more than a meter from their home shelter.

MORPHOMETRICS

The meristics of *C. nicholsii* from the sampled areas are rather uniform (Table 1). However, pectoral ray counts from British Columbia are lower than those from the southernmost locality (Isla San Martín).

Pelagic prejuveniles were sampled in southern California from San Pedro Basin, San Juan Seamount, and between Anacapa and Santa Cruz Islands. Variation in the pelagic prejuveniles was similar to that in the juvenile-adult sample with the exception of the first dorsal spines and scale counts. For the scales the explanation is one of delayed development. Variation in dorsal spines between the age groups may be the result of delayed development or perhaps some spines were overlooked.

Morphological data for three localities were considered in size groups in Table 2. Although adequate samples were not available from Baja California or British Columbia, no notable trend of morphological variation was evident. Differences in proportions were observed in fin ray lengths. As *C. nicholsii* exhibits sexual dimorphism of some body parts (particularly fins) morphological comparisons should be made on the basis of individual sex, but sample sizes were inadequate for such analyses.

FOOD HABITS

Food studies were conducted to identify the major foods, to determine if differences in seasonal utilization occurred, and to disclose any variation in the foods taken by fish of different sizes. Three methods of analysis were used: numerical, volumetric, and frequency-of-occurrence. Of the 106 stomachs examined, two were empty, and were not included in the calculations.

It appears that crustaceans are the principal food item of *C. nicholsii* (Fig. 2); they were found in nearly all stomachs examined, generally in the greatest numbers, and formed the bulk of the volume. Numerically crustaceans comprised 90.9% of the food items; mollusks (4.8%) were second. Other food items, such as annelids, echinoderms, etc., were usually found in small numbers.

By volume crustaceans made up 79.0% of the diet; mollusks again were second (4.6%). Other foods composed a small portion of the diet.

Crustaceans occurred in 97.0% of the stomachs analyzed (Fig. 2). Although found in small quantities numerically and volumetrically, mollusks occurred in 63% of stomachs examined. Bryozoans, which accounted for only 0.4% of total food volume, were found in 37% of stomachs examined. As this goby was not observed to selectively bite off pieces of bryozoans on the reefs it is possible that these organisms were picked up incidentally along with the preferred bottom-dwelling food items. Bryozoans are relatively indigestible and are probably retained in the gut for some time, which may account for their apparent abundance.

Table 1. Meristic variation in juveniles to adults and in pelagic prejuveniles of *Coryphopterus nicholsii*

Locality	First dorsal spines			Second dorsal rays (total)				Anal rays (total)				Pectoral rays (each side)				Scales along midline							
juveniles to adults	4	5	6	12	13	14	15	11	12	13	14	21	22	23	24	21	22	23	24	25	26	27	28
Baja California, Mexico																							
Isla San Martín.			3		2	2			2	2				4	4					2	2		
Punta Colnett			1			1			1			1	1								1		
Punta Banda (SW).			41		9	21	11		32	6	2		35	41	4				4	13	13	15	1
Islas Los Coronados.			3		1	2			3				1	3	2					1	3	1	1
Southern California																							
Laguna Beach			196		41	144	15	7	166	24	1	15	171	175	31			5	7	80	88	33	5
Santa Catalina Island		1	24		8	16			21	2			45	27	4				5	13	10	1	
Santa Rosa Island			46	1	15	30			42	4			21	43	26				6	25	28	12	
San Nicholas Island			8		2	7			7	2			2	11	3					4	8		
British Columbia																							
Hunt Island			20		14	6		4	13	3		4	32	4					7	8	17	4	
Southern California (totals)																							
Pelagic prejuveniles[1]	1	4	19	1	5	17		1	19	4		7	13	16	2	3	1	3	2	6	2	5	
Juveniles to adults		1	274	1	66	197	15	7	236	32	1	15	239	256	64			5	18	122	134	46	5

[1]Pelagic prejuveniles from San Pedro Basin, San Juan Seamount, and between Anacapa and Santa Cruz islands, all off southern California.

Table 2. Comparison of morphometrics among populations of *Coryphopterus nicholsii*

		Punta Banda, Baja California			Laguna Beach, California			Hunt Island, British Columbia		
Proportions	S.L.	N	Range	Mean	N	Range	Mean	N	Range	Mean
standard length										
head length	22-39mm	11	3.0-3.4	(3.30)	39	3.0-3.6	(3.30)			
	40-55	17	3.1-3.8	(3.39)	56	3.1-3.7	(3.40)			
	56-75	18	3.2-4.0	(3.60)	86	3.3-3.9	(3.46)	9	3.6-3.9	(3.75)
	76-92				26	3.3-4.2	(3.65)	17	3.3-4.0	(3.76)
standard length										
body width	22-39mm	11	5.7-8.4	(7.46)	37	7.0-10.6	(8.48)			
	40-55	9	6.7-7.8	(7.33)	45	6.1-8.7	(7.25)			
	56-75	17	6.6-8.1	(7.35)	51	5.9-8.5	(6.60)			
	76-92				28	5.9-8.8	(7.28)			
standard length										
length base 1st dorsal	22-39mm	11	5.7-6.4	(6.17)	39	5.3-7.2	(6.28)			
	40-55	14	4.7-5.8	(5.30)	51	4.9-7.1	(5.67)			
	56-75	18	5.1-6.1	(5.59)	75	4.9-6.2	(5.41)	10	5.0-6.0	(5.50)
	76-92				23	4.6-6.1	(5.20)	17	4.8-6.1	(5.25)
standard length										
length base 2nd dorsal	22-39mm	11	3.4-4.0	(3.80)	39	3.4-4.1	(3.82)			
	40-55	15	3.4-3.8	(3.58)	54	3.0-3.8	(3.56)			
	56-75	18	3.4-4.2	(3.74)	76	3.3-3.9	(3.51)	10	3.5-3.8	(3.64)
	76-92				23	3.2-4.0	(3.54)	17	3.3-4.2	(3.67)
standard length										
length base anal	22-39mm	11	3.9-4.9	(4.69)	38	3.4-4.8	(4.78)			
	40-55	13	4.3-4.9	(4.54)	49	3.9-5.1	(4.61)			
	56-75	18	4.4-4.8	(4.56)	79	4.1-5.0	(4.69)	10	4.4-4.8	(4.56)
	76-92				24	4.0-4.9	(4.52)	17	4.2-5.0	(4.54)
standard length										
length of longest pectoral ray	22-39mm	11	3.0-3.6	(3.40)	38	3.1-3.9	(3.51)			
	40-55	16	3.3-3.9	(3.46)	52	3.1-4.3	(3.60)			
	56-75	18	3.1-4.0	(3.51)	70	3.1-4.0	(3.69)	3	3.1-3.2	(3.17)
	76-92				21	3.2-3.9	(3.55)	17	2.8-3.5	(3.22)
standard length										
length of longest 2nd dorsal ray	22-39mm	11	2.4-2.8	(2.53)	28	2.4-2.5	(2.45)			
	40-55	16	3.2-3.7	(2.74)	11	2.1-2.5	(2.32)			
	56-75	18	2.0-2.2	(2.15)	34	1.9-2.4	(2.23)	3	2.0-2.1	(2.03)
	76-92				18	1.9-2.3	(2.10)	17	1.7-2.0	(1.89)
standard length										
body depth	22-39mm	11	4.4-5.4	(4.97)	39	4.5-5.9	(5.18)			
	40-55	16	4.5-5.5	(4.98)	50	4.4-5.9	(5.35)			
	56-75	18	4.6-5.6	(5.00)	73	4.1-6.1	(5.05)	3	4.9-5.3	(5.10)
	76-92				23	4.5-6.1	(5.27)	17	4.8-5.9	(5.39)
standard length										
length of longest pelvic ray	22-39mm	11	4.0-4.4	(4.21)	39	4.1-4.7	(4.40)			
	40-55	3	4.3-4.5	(4.37)	11	4.1-5.1	(4.48)			
	56-75	4	3.9-4.6	(4.38)	28	3.5-5.1	(4.55)	3	4.2-4.8	(4.44)
	76-92				19	4.3-4.8	(4.66)	17	3.9-4.5	(4.25)
standard length										
length of longest anal ray	22-39mm	3	2.8-3.4	(3.03)	35	2.9-3.0	(2.97)			
	40-55	3	2.6-2.8	(2.74)	12	2.7-3.4	(2.89)			
	56-75	4	2.6-2.8	(2.75)	28	2.4-3.0	(2.74)	3	2.5-2.7	(2.56)
	76-92				17	2.3-2.9	(2.56)	16	2.1-2.7	(2.18)
head length										
length upper jaw	22-39mm	4	2.5-3.2	(2.65)	35	2.4-3.2	(2.82)			
	40-55	16	2.3-3.1	(2.66)	56	2.3-3.2	(2.86)			
	56-75	7	2.4-2.9	(2.64)	77	2.1-3.2	(2.55)	3	1.9-2.8	(2.40)
	76-92				22	2.2-2.7	(2.44)	16	2.3-2.7	(2.45)
head length										
head width	22-39mm	4	1.6-1.7	(1.62)	36	1.5-2.1	(1.75)			
	40-55	16	1.3-1.7	(1.49)	59	1.4-1.8	(1.51)			
	56-75	7	1.3-1.5	(1.43)	77	1.2-1.8	(1.42)	3	1.4-1.5	(1.43)
	76-92				24	1.2-1.6	(1.37)	17	1.3-1.7	(1.54)
head length										
snout length	22-39mm	4	3.5-4.9	(4.06)	36	3.3-4.5	(3.84)			
	40-55	15	3.2-4.0	(3.51)	56	3.2-3.9	(3.42)			
	56-75	7	3.1-3.9	(3.34)	78	2.9-4.0	(3.57)	3	2.9-4.5	(3.63)
	76-92				22	3.1-4.0	(3.45)	17	3.5-4.4	(3.99)
head length										
length of eye	22-39mm	4	3.2-4.3	(3.52)	35	3.1-3.8	(3.30)			
	40-55	15	2.9-3.8	(3.04)	54	2.9-3.9	(3.36)			
	56-75	7	3.1-3.9	(3.46)	78	2.9-4.2	(3.52)	3	2.5-3.3	(2.97)
	76-92				24	3.3-4.0	(3.61)	17	3.1-3.6	(3.45)

Echinoderms (mainly sea urchin spines and tests) were also found in relatively high frequency (26%), probably for the reasons discussed for bryozoans. The nutritional importance of bryozoans and echinoderms is seemingly small.

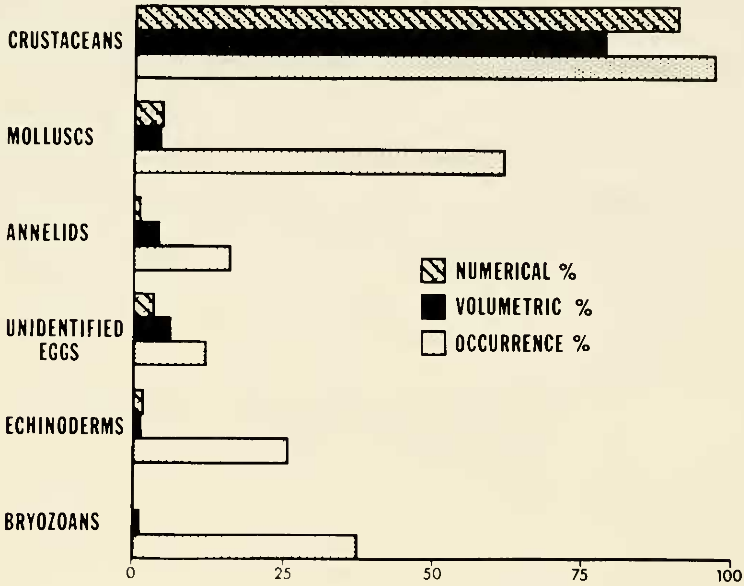


Figure 2. Analysis of 106 stomach contents of *Coryphopterus nicholsii* taken at Laguna Beach, California, from October 1966 to September 1967.

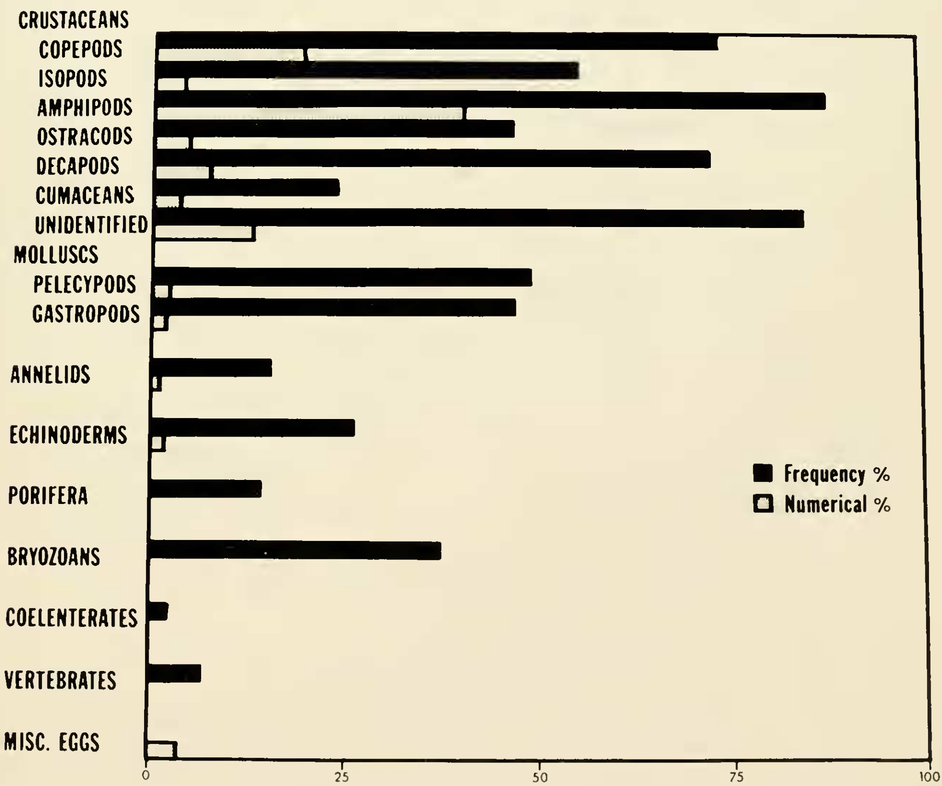


Figure 3. Further analysis of the stomach contents of *Coryphopterus nicholsii* expressed as numerical and frequency-of-occurrence percentages.

Measurements and counts from the mollusks were taken with the shell intact. However, for accurate evaluation, only the digestible parts should be considered. This was not possible, because of the small size of the food items. Because mollusk shells are relatively undigestible, and they may be retained in the stomach, data for this element are probably biased. Some shells may have been picked up incidentally along with the substrate as the goby grabbed for a desired bottom-dwelling organism. Empty gastropod shells could also be the shelter of hermit crabs, an important part of the decapod element of the diet. The crabs are presumably digested rapidly, whereas the shells may accumulate in the gut. These emptied hermit crab shelters would then be categorized as a mollusk element even though the food item selected by the goby was a crustacean.

Amphipods (39.9% numerically) and copepods (19.6% numerically) were the most abundant crustaceans taken by *C. nicholsii* (Fig. 3). One stomach contained 256 amphipods. Isopods (3.6%) and decapods (6.8%) also made up an important part of the diet.

Amphipods were found in 88% of the stomachs examined. Copepods (74%), decapods (73%) and isopods (55%) were also found in most stomachs (Fig. 3). Although pelecypods and gastropods composed only 2.5% and 2.3% of the total number of food items respectively, pelecypods were found in 49% and gastropods in 47% of all stomachs examined (Fig. 3).

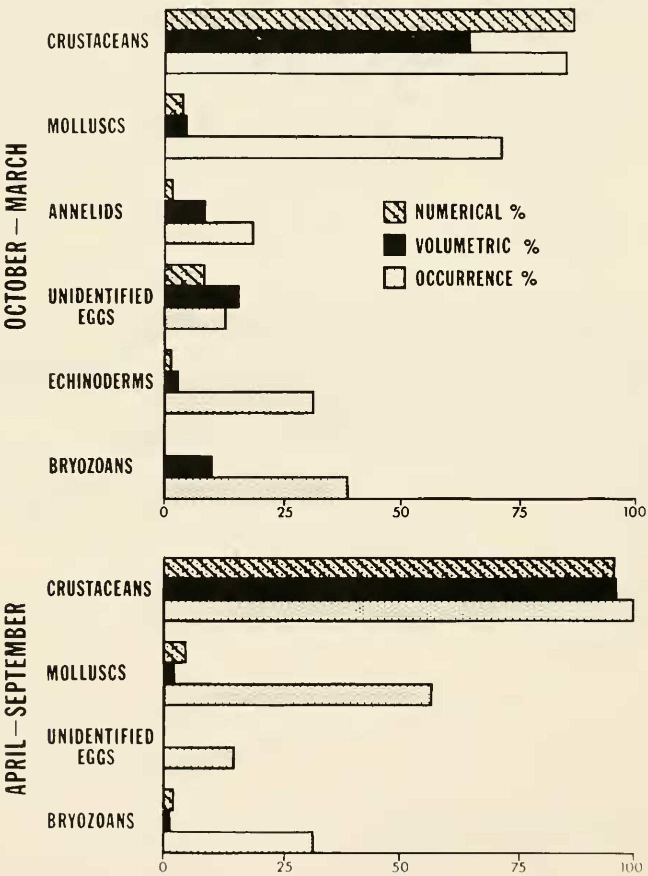


Figure 4. Seasonal analysis of the stomach contents of *Coryphopterus nicholsii*.

Coryphopterus nicholsii exhibited seasonal variation in food utilization (Fig. 4). Crustaceans were the major food item in both the October-March sample (numerical: 87.7%; volumetric: 66.0%) and the April-September sample (numerical: 94.0%; volumetric: 95.5%). Mollusks apparently became more important in October-March (numerical: 4.5%; volumetric: 4.6%) as compared to April-September (numerical: 5.3%; volumetric: 1.5%). The other food classes, e.g., echinoderms, annelids, etc., also became more important during the Fall and Winter.

The frequency analysis also showed a similar pattern of seasonal food use (Fig. 4). Crustaceans were found in 86% of the October-March stomachs and 98% of the April-September stomachs. Mollusks were found in 70% of the October-March samples, but in only 58% of the April-September samples. Thirty-two percent of the October-March stomachs contained echinoderms, but only 18% of the April-September stomachs contained this food.

Benthic organisms, such as mollusks, echinoderms, annelids and bryozoans, were found more frequently in the October-March period. Also in the October-March sample the crustacean element shifted somewhat to more benthic forms such as decapods, cumaceans, and ostracods, with concomitant decreases in copepods and other swimming and planktonic forms. This shift in diet perhaps reflected changes in populations of the latter groups.

Copepods composed 100% (N = 47) of the food of four pelagic postlarvae (18.7-21.1 mm) from the San Juan Seamount, California. One stomach contained a single scale. No gross differences in diet were noted between size classes or sexes once the gobies had assumed a benthic existence.

POPULATION STRUCTURE

The Laguna population showed a sex ratio of 1.7 females to 1 male (165 females and 96 males). The sex ratio seemingly fluctuated somewhat, but the paucity of data for some months precluded a complete analysis.

Scales provided satisfactory material for aging *C. nicholsii*, and scale analysis demonstrated the relation between age and size (Fig. 5). Modes in the length-frequency distributions agree well with the observed ages, although overlap occurs due to the differential growth and prolonged spawning period.

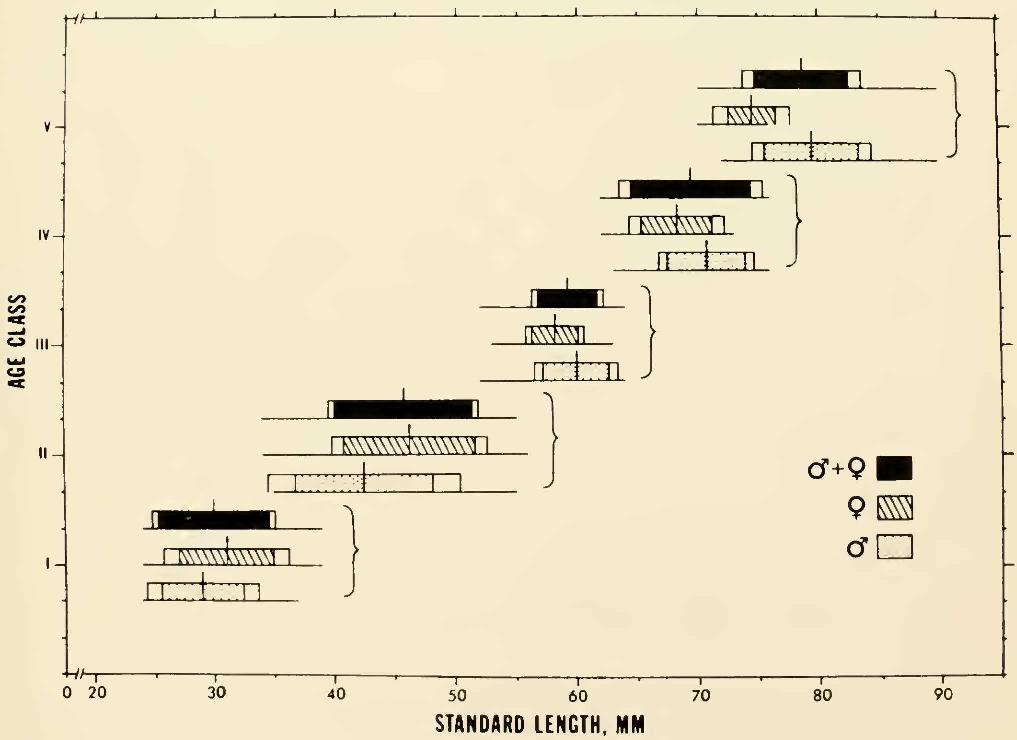


Figure 5. Empirical growth rate of *Coryphopterus nicholsii* from Laguna Beach, California, based on scale analysis of 134 specimens collected from October 1966 through January 1968. Vertical line represents mean; horizontal line, the range of variation; longer rectangle, one standard deviation on either side of the mean; shorter rectangle, 2 standard errors on either side of the mean.

Young gobies were first observed on the Laguna reefs in February. These individuals, which ranged from 21.8 to 26.2 mm in standard length, were probably ones that had hatched the previous year. Growth during the pelagic period is considerable as the newly-hatched larvae measure under 3.0 mm in total length.

Scales of *C. nicholsii* form during the pelagic period. One specimen showed some well developed scales at 19.5 mm on 28 December 1966. However, the majority of specimens did not show scales until they had attained a length of 21.1 mm or greater. This is the approximate size at which *C. nicholsii* settled on the reefs in 1967. The first annulus is not laid down until the following winter.

The observed length-frequencies of *C. nicholsii* collected at Laguna Beach (Fig. 6) usually corresponded with the observed age-groups indicated by scales in that five (sometimes four) frequency groups were represented in the samples. Males of any frequency group were relatively larger (as indicated by mean standard length) than females of the same group.

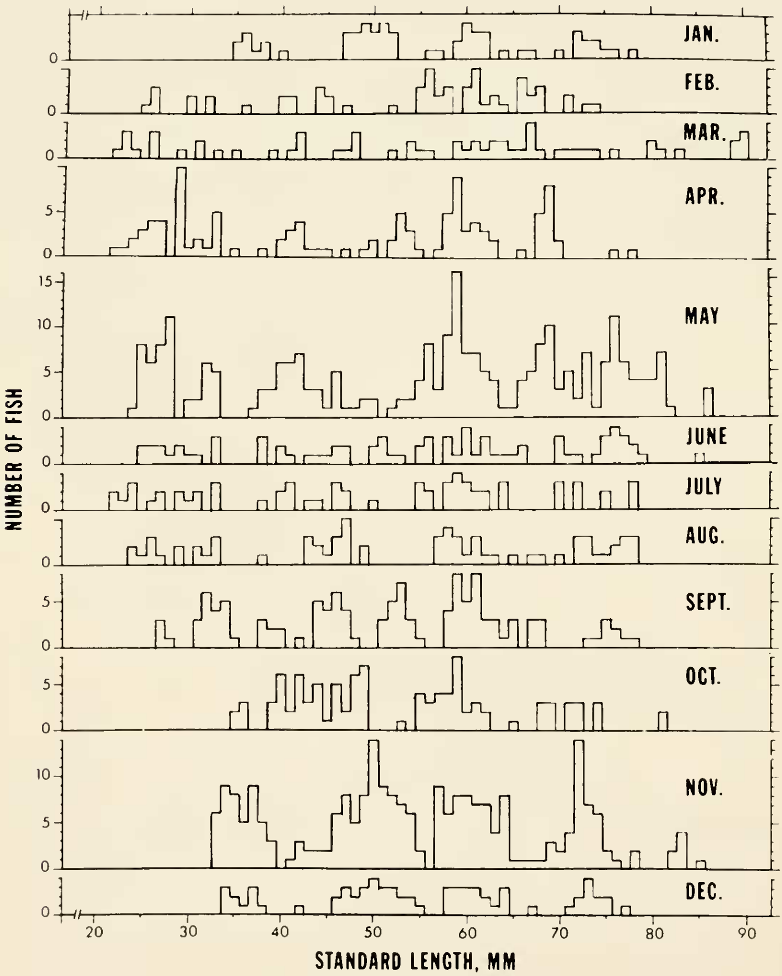


Figure 6. Length-frequency measurements of 1325 specimens of *Coryphopterus nicholsii* taken at Laguna Beach, California, from October 1966 through September 1967.

PREDATION

One incident of predation on *C. nicholsii* was observed on the shallow Laguna reef. A small sand bass (*Paralabrax nebulifer*) caught and ate a *Coryphopterus* after I flushed the goby away from the shelter of the reef onto the surrounding open sand. Subsequent collections of

22 sand bass on the reef revealed that 7 (32%) had fed on *C. nicholsii.* Turner, Ebert and Given (1969) did not find *C. nicholsii* in the stomach of large predaceous fish collected on reefs between 1960 and 1963, although this goby was abundant and appeared to be a suitable food item. Smith (1970) and Quast (n.d.b.) list Gobiidae as a food of kelp bass (*Paralabrax clathratus*).

Stomach analyses of bluebanded gobies, *Lythrypnus dalli,* another common inhabitant of the southern California rock reef, revealed larval *C. nicholsii* in 2 of 42 (4.8%) stomachs. Investigations were not made on the food habits of other possible predators on the reefs inhabited by *C. nicholsii.*

Turner, Ebert and Given (1969) observed a 3 mm larval *C. nicholsii* entrapped in the hydranth of an *Obelia* on an artificial reef off southern California.

SEXUAL DIMORPHISM

Sexual dimorphism of the genital papilla, is usually evident in the Gobiidae (Dôtu, 1957a, 1958a, 1961a; Miller, 1963; Springer and McErlean, 1961; Tavolga, 1954; Smith, 1964; Weisel, 1947). Dimorphism has also been noted in fin size (Hildebrand and Cable, 1938; Baird, 1965; Dôtu, 1958b, 1959, 1961b), pigmentation (Heincke, 1880; Tavolga, 1954; Ninni, 1938; Dôtu, 1958c, 1961c), shape of mouth (Baird, 1965), and size and shape of the body (Breder and Rosen, 1966; Baird, 1965; Dôtu, 1957b, 1958c, 1961c).

Four hundred specimens of *C. nicholsii* from 9.6 to 88.0 mm in standard length were examined for external sex identification. The genital papilla was found to be sexually dimorphic (Fig. 7). Specimens shorter than 25 mm standard length could not be accurately sexed externally, but those larger than 25 mm were correctly sexed by examination of the papilla, which is elongate and pointed in the male and is broad and truncate in the female.

During the breeding season the males of *C. nicholsii* are easily distinguished from the females by their black pelvic fins. These fins remain light grey throughout the year in the females.

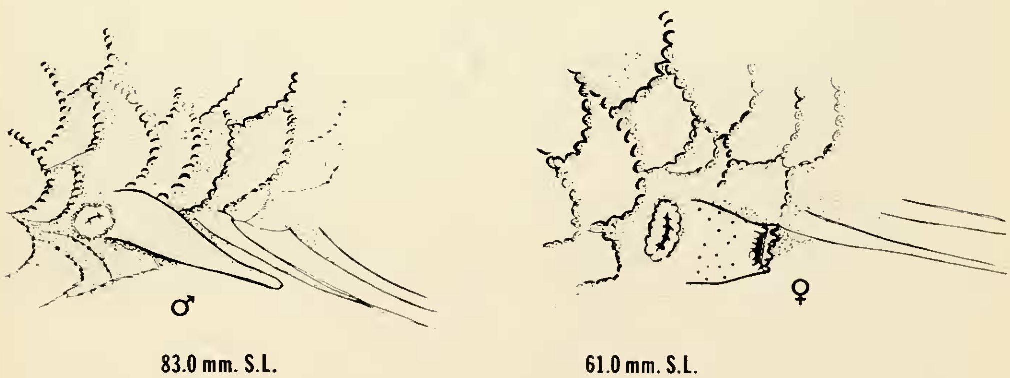


Figure 7. Sexual dimorphism in the genital papilla of *Coryphopterus nicholsii.*

Dimorphism is also discernable in the maximum sizes of the sexes. Males attain a greater length than females. The largest male examined was 90.0 mm in standard length, whereas the largest female was 76.0 mm. Larger size may accord the nest-guarding male greater success in the protection of the eggs.

Examination of the length of the second dorsal and anal fins of mature gobies also revealed sexual dimorphism. Both fins were found to be relatively longer in the male (Fig. 8). Measurement was from the front of the base of the first element to the distal end of the last ray. This dimorphism was not expressed in meristic differences.

REPRODUCTION

The Laguna population was sampled at weekly or biweekly intervals from October 1966 to September 1967 to determine the length of the breeding season. The presence of eggs and individuals of both sexes in breeding condition was used as evidence of reproductive activity.

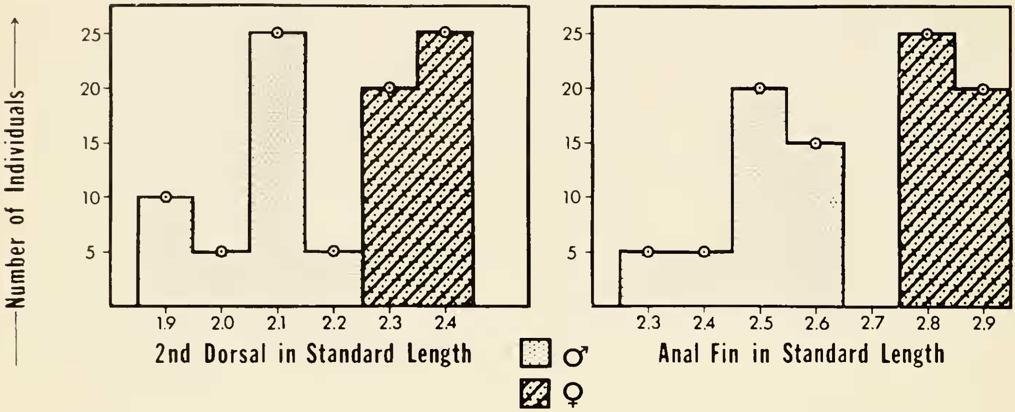


Figure 8. Sexual dimorphism in length of the second dorsal and anal fins of *Coryphopterus nicholsii*, from anterior of base to posterior tip of last ray; expressed as ratio of length of fin into standard length.

Females of *C. nicholsii* were found to be mature at 47.3 mm or larger (Fig. 9). This size corresponds to age-group II as observed from scale and length-frequency analysis. Mature males shorter than 55 mm were not found. This size corresponds with the last of age-group III. However, mature males were found with two or more annuli (age-groups III through V). Ripe females were found in age-groups II through V.

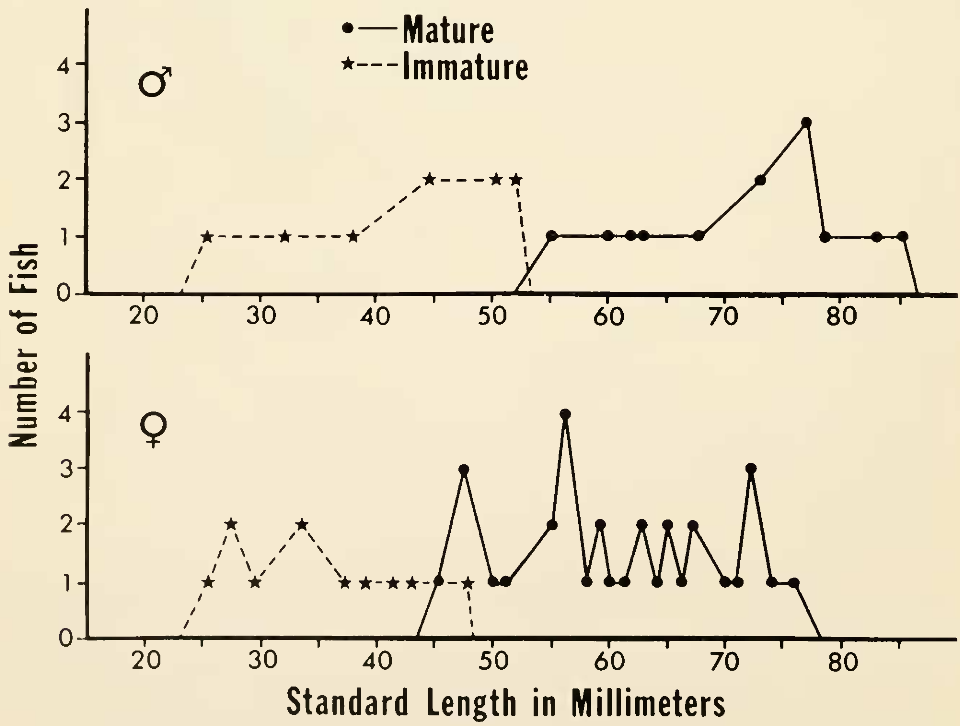


Figure 9. Standard lengths of *Coryphopterus nicholsii* at sexual maturity based on gonad development of 22 males and 43 females from Laguna Beach, California.

The first ripe females, measuring 47.3 to 73.5 mm in standard length, were taken on 10 February 1967. The first ripe males appeared slightly earlier on 2 February 1967; they ranged from 72.1 to 83.0 mm in standard length. No ripe gobies of either sex were found after 26 August 1967 (Fig. 10).

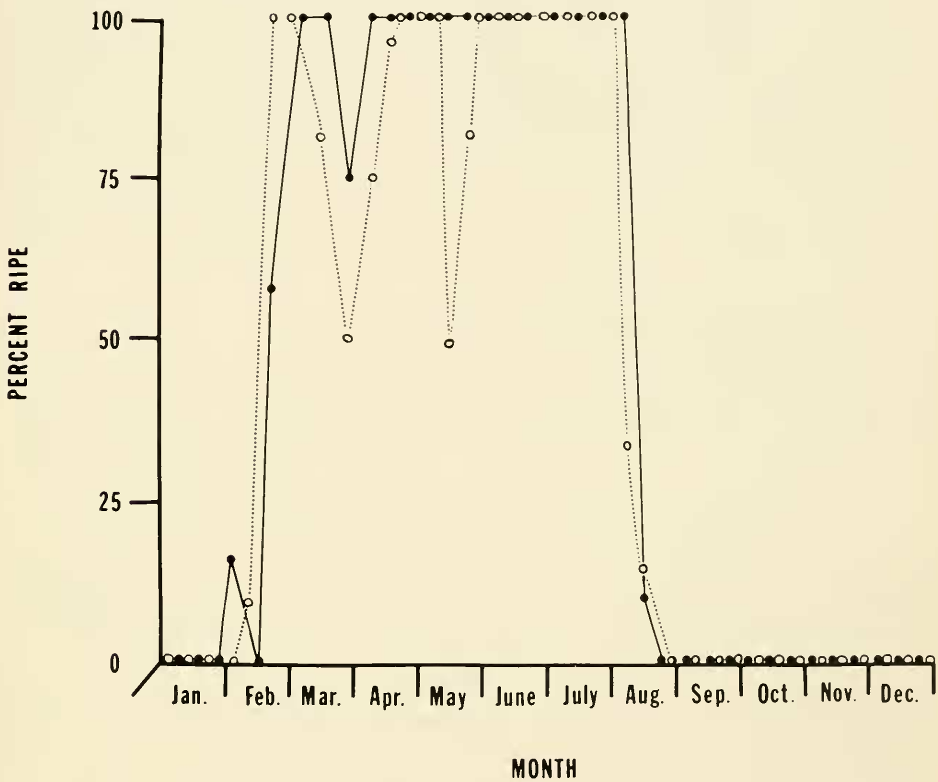


Figure 10. Monthly percentages of ripe *Coryphopterus nicholsii* from Laguna Beach, California. Based on 1134 specimens taken from Laguna Beach, California from October 1966 through September 1967. Solid dots (solid line) represent males, circles (broken line) represent females.

The mature ovaries contained two egg groups, one ripe and one unripe. The ripe egg group seemed to be spawned at one time. The number of ripe ovarian eggs (in both ovaries) was found in four individuals to range from 3274 to 4788. However, the assessment of fecundity in a species which may spawn several times over an extended period, has little biological value per se. I could not determine how many times this species spawned in a season.

Ripe ovarian eggs are orange and round, and measure 0.4 to 0.7 mm. Unripe eggs range in diameter from 0.05 to 0.2 mm.

Eggs were found on the Laguna reefs from 11 April to 5 August 1967. However, because it is difficult to locate the nests, I do not think that these dates wholly encompass the spawning period. Ebert and Turner (1962) observed nests off Hermosa Beach and Santa Monica, California, from April through October.

Fertilized eggs (Fig. 11) have the spindle shape characteristic of gobies. They are attached directly to the rock surface but have no adhesive threads. Ebert and Turner (1962) found that mature eggs averaged 2.10 mm long by 0.48 mm wide. The embryo within each mature egg averages 2.97 mm in length and its head is directed opposite (downward from) the pole of attachment on the lower surface of the nest. Ebert and Turner described the developing embryo.

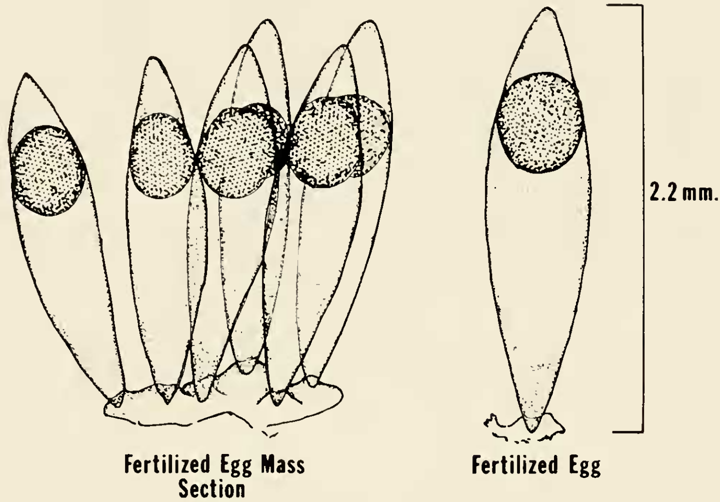


Figure 11. Fertilized eggs of *Coryphopterus nicholsii.*

The prejuvenile of *C. nicholsii* (Fig. 12) is pelagic. Specimens ranging in size from 15.5 to 29.0 mm standard length have been taken 560 km off San Francisco and 260 km off Santa Barbara. One individual was taken on Davidson Seamount, 97 km southwest of Point Sur, California (Berry and Perkins, 1966). These individuals have been described by Berry and Perkins as pelagic, oceanic, protracted prejuvenile stages. Specimens from the vicinity of San Diego ranging from 9.6 to 22.6 mm in standard length, have been examined. These were distinct from the adults in having vertical bars which are burnt orange in life. These bars become light brown in alcohol.

Juveniles of *C. nicholsii* were found to assume a benthic habit on the Laguna study reefs at 21.8 mm standard length. Specimens as short as 24.0 mm were found on other reefs. Fish of this size were found on the Laguna reefs in February through August 1967.

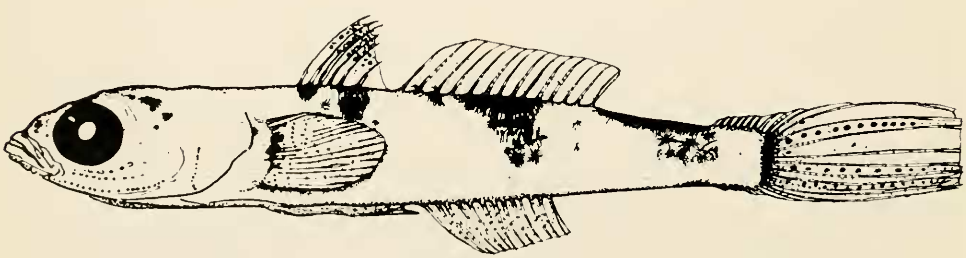


Figure 12. Pelagic prejuvenile of *Coryphopterus nicholsii,* 19.4 mm in standard length, from San Pedro Basin, California.

FEEDING BEHAVIOR

Coryphopterus nicholsii has three feeding-behavior patterns. The most frequent was swimming off the bottom for a distance of about 8 cm, grabbing a small crustacean and then settling. Another pattern involved picking a benthic organism from the substrate. The third involved picking up a mouthful of the loose bottom, spitting it out, and then selecting the desired food as it fell through the water. By the latter two methods such items as decapods, annelids, and echinoderms were taken. These items were probably detected visually, although this species does have moderately developed papillae (Macdonald, 1972) which may function in sensing burrowing organisms.

I noted one exception to the general benthic habit on the southwest coast of Punta Banda, Mexico, where there are many narrow canyons through which strong upwelling currents flow. Gobies there hovered 0.5 to 1.0m off the bottom, using their pectoral fins as the means to counter the current, as they fed on the plankton that drifted up the canyons.

In the aquarium, *C. nicholsii* was fed on frozen brine shrimp. Usually the gobies grabbed the shrimp in midwater, and swallowed them whole. If the shrimp was picked off the bottom the goby would spit it out with the associated rubble and then once again grab the shrimp as it drifted downward. When fed on chunks of frozen smelt, which were too large to be swallowed whole, the gobies, which have moderately developed teeth, bit off large pieces.

BREEDING BEHAVIOR

Gobies and species of various other groups endowed with adherent eggs generally seek some rocky crevice, shell, or other hard object suitable for egg attachment. As is typical of gobioid fishes, and most territorial fishes, the male *C. nicholsii* selects and prepares the nest (Tavolga, 1954; Dôtu, 1958a; Guitel, 1893). Nest building is intermittent, alternating with courtship and other phases of social behavior. The male enters and leaves his shelter frequently. The duration of the stay within the shelter is highly variable.

Nest preparation consists of several cleaning movements, similar to those described by Tavolga (1954) for *Bathygobius soporator:* fanning, rubbing, scooping, and nibbling. Fanning the most frequent act, consists of the vigorous waving of the body and pectoral fins, sending up a cloud of sand for several seconds. This appears to be the most efficient type of digging activity for this fish. Rubbing consists of brushing the body against the algae-covered surface of the nest, apparently to dislodge this material. Scooping is accomplished by taking mouthfuls of sand, small shells, or other debris and carrying it away from the nest. Nibbling may occur if the shelter has algae or other material clinging to its surface. Nest cleaning is not thorough and the adhesive algae and other organisms are not cleaned off completely.

Essentially the same nest-preparation movements observed in *C. nicholsii* have been described for other species of gobies, as well as for most teleosts that construct any sort of hollow in sand substrates. The fanning method of nest formation is probably the most widespread of the nesting behaviors in fishes and has been described for the *Centrarchidae* (Breder and Rosen, 1966), certain cichlids (Baerends and Baerends-Van Roon, 1950), and *Clinocottus* and other cottids (Breder and Rosen, 1966).

When courting, each male rose a few centimeters off the bottom, spread his fins fully, and settled back to the substrate. After one to several of these displays, he swam back to his nest, where he continued nest construction for a short time, and then resumed his courting.

Intermittently the male swam swiftly toward the female and then quickly returned to his starting place, apparently in an attempt to stimulate the female and to attract her to his nest site. If the female reacted negatively, the male followed and continued courting, often nipping and chasing her. Early in courtship the female simply darted away into other shelters. Prior to spawning the female often took shelter in the male's nest, from which she was chased. However, the male, upon seeing the female within the nest, approached with courting movements before entry and chasing. Apparently the male faced a conflict situation between defense of his nest and enticing the female to remain and spawn. Occasionally a female approached a male that was courting her. The female then slowly undulated the body, gaped, and spread the fins.

Some form of courtship behavior is exhibited by males of most nesting species of fishes. There is considerable interspecific variation in the details of this behavior within gobiids. The courting male of *Gobius minutus* exhibits body tremors and rapid breathing movements while approaching the female with short hops, his fins bristling, head raised, throat puffed, and mouth agape (Guitel, 1892). Males of *Gobiosoma* approach the female with short darts, with fins widely spread (Breder, 1942). Courting males of *Brachygobius xanthozonus* swim back and forth in front of the female (Field, 1945). The courtship display of a male *Elacatinus oceanops* consists of violent swimming while he clings to the substrate with the pelvic cup; he then butts the female in the head and genital regions with his nose, and slaps her on the head with his caudal fin (Feddern, 1967). The male of *Bathygobius soporator* slowly approaches the female and positions himself beside or in front of her; he then waves his body, tail, and pectorals in a manner similar to that involved in nest cleaning; if the female moves away, the male follows and continues courting, often chasing and nipping her (Tavolga, 1954).

A change in the color of the pelvic fin of *Coryphopterus nicholsii* males during the breeding season presumably stimulates courtship response by the female. Color changes have been noted in various fins of other gobiid fishes during the breeding season (Dôtu, 1956; Kinzer, 1960). Tavolga (1954) showed that *Bathygobius soporator* females can at times "recognize" males by coloration, in the absence of any courtship activity. That the male's black pelvic fin may provide adequate stimulus for sexual recognition was suggested in an experiment wherein an adult female with artificially blackened pelvic fins was approached by a ripe female showing definite courtship behavior.

The female *C. nicholsii* attaches her eggs to the underside of the nest. The deposited egg masses average 10 cm in diameter, are roughly circular and are made up of a single layer of eggs. The male is intermittently present in the nest at the time of oviposition, where he frequently circles the female, butting and biting her. He often passes his turgid genital papilla over the surface of the eggs. Fertilization apparently takes place during and immediately after oviposition.

Among the gobies whose nesting habits have been described, oviposition on the underside of shelters is quite common. Fishes that hide and nest under shelters are likely to be confronted with a nest floor which consists of sand, mud, rubble, or other irregular surfaces, whereas the ceiling will probably present a hard surface more suitable for the adherence of eggs. Also such shelters offer a degree of safety against egg predators.

Tavolga (1950) found that unless artificially fertilized eggs of *Bathygobius soporator* are placed in a hanging position many of the embryos do not rotate properly within their elongate egg cases. Such individuals develop with their heads pointed toward the attached end of the shell and are thus unable to hatch.

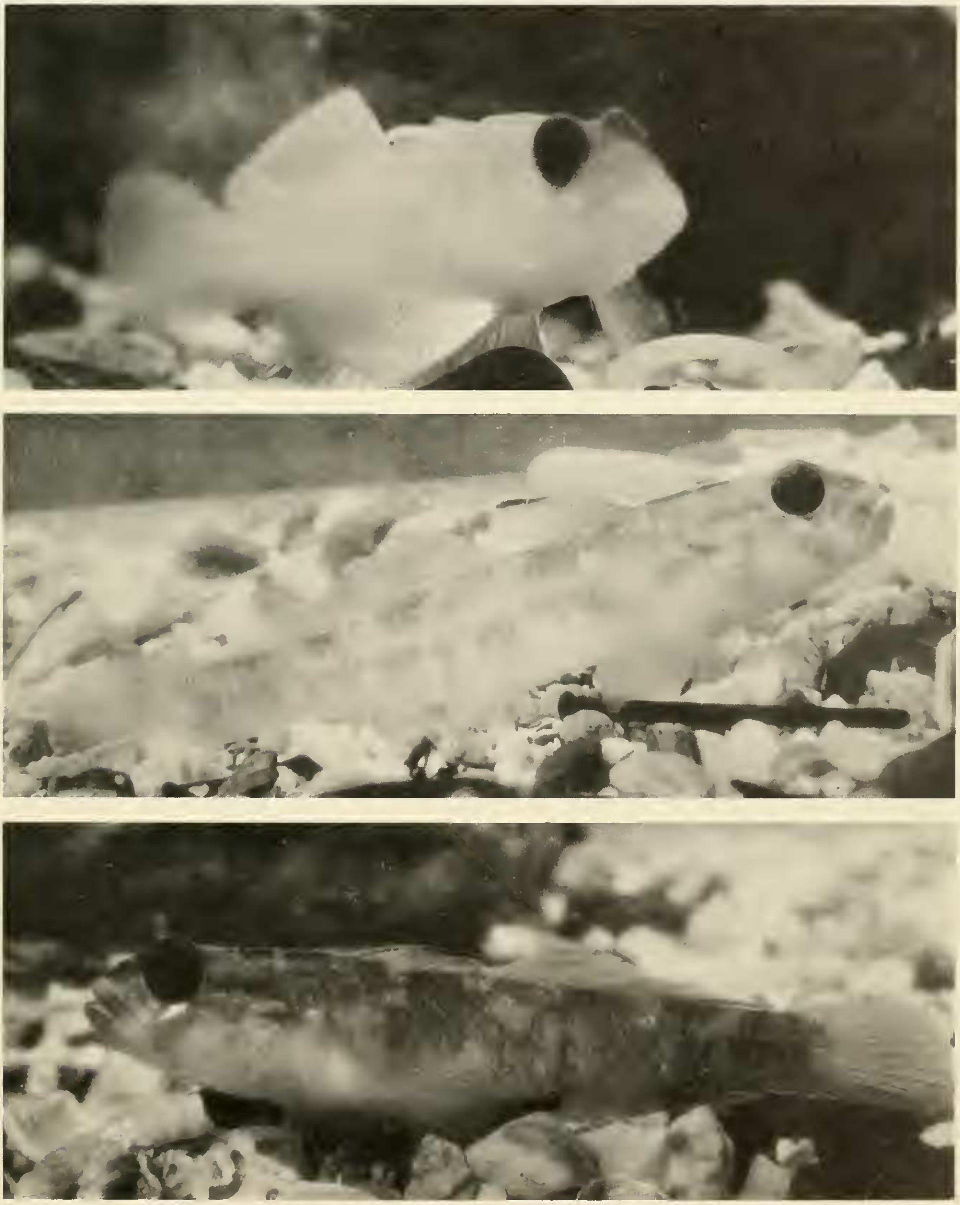
Spawning completed, the male of *C. nicholsii* defends, cleans, and fans the eggs until they hatch. He fans the eggs by intermittently waving his body and pectoral fins. This movement resembles that of nest preparation, and produces a strong current of water over the eggs. The residing male rushes out to chase away any goby or other organism that approaches the nest, as well as a slurp gun placed in front of the nest.

The male guards the eggs in the majority of nesting fishes (Breder and Rosen, 1966). Among the gobies, only *Typhlogobius* is reported as an exception, in that both sexes guard and fan the spawn (MacGinitie, 1939). Brood care by the male of *C. nicholsii* consists almost exclusively of fanning with some or all of the fins. Brood care is practiced by most nesting fishes. The function of the brooding is three-fold: circulation of water for respiration, prevention of bacterial and fungal growth, and defense of the eggs. Tavolga (1954) proposed another function in that the fanning activity of the male in some way prevents the abnormal positioning of the embryos within the eggs.

SOCIAL BEHAVIOR

Coryphopterus nicholsii is a bottom dweller. Its swimming activity is confined to short, quick spurts for feeding, for territory defense, and for escape to shelter. Although it is able to change color and pattern according to the habitat, its light color is generally retained even in dark, rocky areas. This light color blends well with the sand bottom, which appears to be the preferred substrate type of this goby. The black eyes and tip of the first dorsal, although conspicuous to the human observer, may serve as disruptive markings, breaking up the shape of the goby before a predator.

Like many other gobies (Stebbins and Kalk, 1961; Tavolga, 1954), *C. nicholsii* exhibits territorial behavior. It is a solitary species that sets up a territory that includes a shelter and a feeding-display area in front of it. The juxtaposition of the territories, which may be spaced less than 25 cm between shelter centers, induces numerous encounters between neighboring individuals. In the aquarium any available shelter, including a tank corner, was utilized and fought over. The species was quite aggressive in a tank containing several fish; there was almost continuous nipping and chasing.



A

B

C

Figure 13. Changes in coloration of *Coryphopterus nicholsii* during social interaction. A. Normal light coloration of undisturbed or dominant individual. B. Intermediate darkening of submissive goby. C. Final darkened coloration of submissive goby. Note light spot under eye. This spot is blue in life and gives rise to the vernacular name, bluespot goby.

A variable nip order was established which was somewhat, but not absolutely, correlated with size (see also Bopp, 1957; Tavolga, 1954). Social orders were established very quickly. During the breeding season, spawning males, which were the largest individuals, appeared to be dominant. Subdominant members retreated to higher levels of the aquarium, hanging on the tank walls and corners by means of continuous swimming movements of the fins and by the suction of their fused pelvic fins. Some attempted to jump out of the tank.

The fundamental color of *C. nicholsii* is uniform pale yellow, but the coloration is variable, changing rapidly in response to different social situations. During social interactions the subordinate animal usually becomes much darker, and is mottled (Fig. 13). One subordinate individual which had been displaced from the bottom of the tank took up a position three-fourths of the way up the tank wall next to the filter siphon which had evenly spaced holes with growths of dark algae. The color pattern of the fish quickly matched that of the siphon holes. This individual held this position and retained this color pattern for several days.

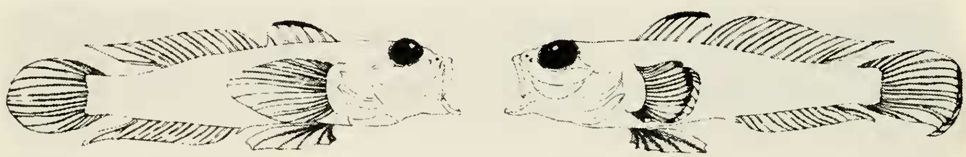


Figure 14. Combat-threat posturing behavior of adult males of *Coryphopterus nicholsii* in aquarium.

The highest degree of aggressive behavior was observed in encounters between mature fish of about equal size. The two gobies approached each other with slow undulations of the body, and with all fins stiffly erected. They positioned themselves next to one another, directly head on (Fig. 14), or head to tail. The mouth was then widely gaped, with the throat expanded and the head elevated. The two gobies displayed either alternately or simultaneously. The "loser" assumed the mottled color pattern and dashed to the safety of shelter.

Interactions between fish of different sizes, or after a hierarchy has been established, usually involve a quick dash by one of the fish, the more dominant one, with the other fish retreating. The more dominant fish nips the fins and scales of the retreating individual. In the laboratory, the fish of the higher rank continually attacked the subordinate intruders if the tank was not large enough to provide adequate territories for the gobies present.

Pugnacity, a feature common to gobies and most territorial fishes, is expressed in *C. nicholsii* as a simple type of biting and pursuit behavior between combatants. Guitel (1892) described similar darkening, throat puffing, gaping, and fin stiffening in *Gobius minutus.* Breder (1942) reported that males of *Gobiosoma robustum* exhibit darkening and fin spreading as intimidation mechanisms. Tavolga (1954) found *Bathygobius sporator* also exhibits color changes correlated with fighting and with reproductive behavior, especially in males, and that extreme darkening is characteristic of fighting males; this occurs together with throat puffing, gaping, quivering, butting, and biting movements. Weisel (1947) found that intimidation behavior of *Gillichthys mirabilis* consists almost entirely of the display of its huge gape.

ACKNOWLEDGMENTS

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